U.S.S.N. 10,655,972

Claim Amendments

Please amend claims 1-4, 6, 7, 12-15, 17-20 as follows:

Please cancel claims 5 and 16 as follows:

Please add new claims 21 and 22 as follows:

Listing of Claims

1. (currently amended) A method for forming a copper damascene feature with improved electrical properties including reducing moisture and etching residues from a damascene opening comprising the steps of:

providing a semiconductor process wafer comprising at least one ~~via~~ damascene opening formed to extend through a thickness of at least one dielectric ~~insulating~~ layer, said opening comprising one of a single damascene opening and ~~an overlying trench line opening encompassing the at least one via opening to form~~ a dual damascene opening;

etching through an etch stop layer at the at least one ~~via~~ damascene opening bottom portion to expose an underlying copper area;

then carrying out a sub-atmospheric DEGAS process in-situ with simultaneous heating of the process wafer in a hydrogen containing ambient;

then carrying out an in-situ sputter-clean process; and,

then forming a barrier layer in-situ to line the ~~dual~~ damascene opening.

2. (currently amended) The method of claim 1, further comprising the steps of:

forming a copper seed layer in-situ to line the ~~dual~~ damascene opening;

carrying out an electrochemical copper deposition process to fill the ~~dual~~ damascene opening with a copper layer; and,

carrying out a CMP process to remove the copper layer and the barrier layer above the ~~trench~~ opening level.

3. (currently amended) The method of claim 1, wherein the hydrogen containing ambient consists essentially of hydrogen and at least one inert gas, said ambient ~~is~~ provided at a pressure of about 1 mTorr to about 10 Torr ~~and a hydrogen gas concentration of about 1% to about 20% with a remaining portion consisting essentially of inert gas~~.

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4. (currently amended) The method of claim 3, wherein the hydrogen containing ambient is provided at a pressure of about 1 mTorr to about ~~100~~ mTorr.

5. cancelled

6. (currently amended) The method of claim 1, wherein the [[a]] sub-atmospheric DEGAS process is carried out at a temperature between about 100 °C and about 500 °C.

7. (currently amended) The method of claim 1, wherein the [[a]] sub-atmospheric DEGAS process is carried out at a temperature between about 250 °C and about 450 °C.

8. (original) The method of claim 1, wherein the sub-atmospheric DEGAS process is carried out for a period of between about 20 seconds and about 120 seconds.

9. (original) The method of claim 1, wherein the barrier layer comprises at least one layer selected from the group consisting of refractory metals, refractory metal nitrides, and silicided refractory metal nitrides.

10. (original) The method of claim 9, wherein the barrier layer comprises at least one layer selected from the group consisting of Ta, Ti, TaN, TiN, TaSiN, and TiSiN.

11. (original) The method of claim 1, wherein the sputter-clean process comprises hydrogen gas.

12. (currently amended) A method for forming [[a]] copper damascene features in low-K [[a]] porous dielectric ~~insulating~~ layers with improved electrical properties including reducing moisture and etching residues from a damascene opening comprising the steps of:

providing a semiconductor process wafer comprising at least one ~~via~~ damascene opening formed to extend through a thickness of at least one porous inorganic low-K dielectric ~~insulating~~ layer, said opening comprising one of a single damascene opening and ~~an overlying trench line opening encompassing the at least one via opening to form~~ a dual damascene opening;

etching through an etch stop layer at the ~~at least one via~~ damascene opening bottom portion to expose an underlying copper area;

then carrying out in-situ a sub-atmospheric DEGAS process with simultaneous heating of the process wafer in a hydrogen containing ambient;

then carrying out an in-situ sputter-clean process comprising hydrogen gas; and,

then forming a barrier layer in-situ to line the ~~dual~~ damascene opening.

13. (currently amended) The method of claim 12, further comprising the steps of:

forming a copper seed layer in-situ to line the ~~dual~~ damascene opening;

carrying out an electrochemical copper deposition process to fill the ~~dual~~ damascene opening with a copper layer; and,

carrying out a CMP process to remove the copper layer and the barrier layer above the ~~trench~~ opening level.

14. (currently amended) The method of claim 1<u>2</u>, wherein the hydrogen containing ambient <u>consists essentially of hydrogen</u> and <u>at least one inert gas, said ambient</u> ~~is~~ provided at a pressure of about 1 mTorr to about 10 Torr ~~and a hydrogen gas concentration of about 1% to about 20% with a remaining portion consisting essentially of inert gas~~.

15. (currently amended) The method of claim [[3]]<u>14</u>, wherein the hydrogen containing ambient is provided at a pressure of about 1 mTorr to about 100 mTorr.

16. cancelled

17. (currently amended) The method of claim 1<u>2</u>, wherein the [[a]] sub-atmospheric DEGAS process is carried out at a temperature between about 100 °C and about 500 °C.

18. (currently amended) The method of claim 1<u>2</u>, wherein the a sub-atmospheric DEGAS process is carried out at a temperature between about 250 °C and about 450 °C.

19. (currently amended) The method of claim 1<u>2</u>, wherein the sub-atmospheric DEGAS process is carried out for a period of between

about 20 seconds and about 120 seconds.

20. (currently amended) The method of claim [[9]] 12, wherein the barrier layer comprises at least one layer selected from the group consisting of Ta, Ti, TaN, TiN, TaSiN, and TiSiN.

21. (new) The method of claim 1, wherein the in-situ steps comprising the sub-atmospheric DEGAS process, the sputter-clean process, and the barrier layer formation process comprise transferring the semiconductor process wafer between said processes in a controlled sub-atmospheric ambient with reduced oxygen levels.

22. (new) The method of claim 12, wherein the in-situ steps comprising the sub atmospheric DEGAS process, the sputter-clean process, and the barrier layer formation process comprise transferring the semiconductor process wafer between said processes in a controlled sub-atmospheric ambient with reduced oxygen levels.